F1-263

UNIVERSITY OF CALIFORNIA, DAVIS

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SANTA BARBARA • SANTA CRUZ

OFFICE OF THE VICE CHANCELLOR FOR RESEARCH
(916) 752-2075
FAX: (916) 752-5432

DAVIS, CALIFORNIA 95616-8671

JUL 25 1997

CALFED Bay-Delta Program Office
1416 Ninth Street, Suite 1155
Sacramento CA 95814

Research Proposal Entitled
"Flow-Temperature Relationships for Clear Creek"
RFP: 1997 Category III Ecosystem Restoration Projects and Programs
Principal Investigator - Gerald T. Orlob

Dear Colleague:

It is our pleasure to present for your consideration the referenced proposal in response to **the CALFED Bay-Delta Program RFP.**

Please call on the principal investigator for scientific information. Administrative questions may be directed to me or my assistant, René Domino, at the above address and phone number. We request that correspondence pertaining to this proposal and a subsequent award be sent to the Office of Research and to the principal investigator.

Sincerely,

Sandra M. Dowdy
Contracts and Grants Analyst

Enclosure

cc: G. T. Orlob

I-005744

I-005744

F1-263

PROPOSAL COVER SHEET

Proposal to: CALFED Bay-Delta Program Office
1416 Ninth Street, Suite 1155
Sacramento, CA 95814

Submitting Organization:
The Regents of the University of California
University of California
Davis, CA 95616

Title of Proposed Research: Flow-Temperature Relationships for Clear Creek

Total Amount Requested	Proposed Duration	Desired Starting Date
$54,634	One Year	October 1, 1997
Principal Investigator:	**Department:**	**Phone Number**
Gerald T. Orlob	CEE	(916) 752-1424

Checks made payable to:
The Regents of the University of California

Send checks to:
University of California
Davis Campus
Cashier's Office, 173 Mrak Hall
Davis, CA 95616

Send Award Notice to:
Office of Research
410 Mrak Hall
University of California
Davis, CA 95616
(916) 752-2075

Approvals:

7/23/97
Principal Investigator Date

Daniel W. Chang 7/23/97
Department Chair Date

7/23
Dean, College/School Date

Other Endorsement Date

Sandra M. Dowdy JUL 25 1997
Official Signing for Organization Date

Sandra M. Dowdy
Contracts and Grants Analyst

I-005745

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COLLEGE OF ENGINEERING
DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING
(916) 752-0586
FAX: (916) 752-7872

DAVIS, CALIFORNIA 95616

July 25, 1997

Ms. Kate Hansel
CALFED Bay-Delta Program
1416 Ninth Street, Suite 1155
Sacramento, CA 95814

Dear Ms. Hansel,

Enclosed please find an original plus nine copies of a proposal titled, "Flow-Temperature relationships for Clear Creek," for your consideration for funding under the CALFED Bay-Delta Program.

If you have any questions, please call me at (916) 752-1424, or you may reach me via e-mail at gtorlob@ucdavis.edu. I look forward to receiving your reply.

Sincerely yours,

Gerald T. Orlob
Professor Emeritus
Civil and Environmental Engineering

FI-263

Proposed Project

Department of Civil and Environmental Engineering
University of California Davis

FLOW - TEMPERATURE RELATIONSHIPS FOR CLEAR CREEK

Principal Investigator: Gerald T. Orlob
Professor Emeritus
Department of Civil and Environmental Engineering
University of California
Davis, CA 95616
Tel: (916) 752-1424
Fax: (916) 752-7872
e-mail: gtorlob@ucdavis.edu

Organization type: University of California, Educational Institution, Tax exempt

Tax Identification no.: 94-6036494-W

Financial Contact Person: Ms. Stephanie Reynolds
Office of Research, College of Engineering
University of California
Davis, CA 95616
Tel: (916) 752-7405
Fax: (916) 752-8058
e-mail: sareynolds@ucdavis.edu

Collaborators: California Department of Fish and Game, field assistance
United State Geological Survey, data assistance

RFP Project Type: Group 3, Services and Other projects

Executive Summary

FLOW-TEMPERATURE RELATIONSHIPS FOR CLEAR CREEK

Department of Civil and Environmental Engineering
University of California Davis

Project Description

Clear Creek is a tributary of the Sacramento River system, joining the river's main stem about 12.5 miles downstream of Keswick Dam, about 5 miles south of Redding. Historically the creek has been an important salmon habitat, but with the construction of Whiskeytown Dam in 1960 the upper reaches of the catchment were isolated, leaving only a 16-mile lower reach of the creek accessible to migrating Chinook salmon. Flow in the creek is largely regulated at the dam in accord with operation of Whiskeytown Reservoir, a major component in the water transfer system of the Shasta-Trinity Division of the Central Valley Project. Because the reservoir is equipped with temperature control curtains designed to minimize warming of water transferred through the Spring Creek Tunnel into Keswick Reservoir, both flows and water temperatures at the upper limit of the active Clear Creek channel are determined by project operation. Further downstream temperatures are governed primarily by heat exchange through the air-water interface and accretions and/or depletions of stream flow. The degree of warming experienced in this reach is a complex function of the flow rate, time of travel, channel morphology and meteorological conditions governing exchange of heat between the atmosphere and the stream. This proposal seeks to determine the quantitative relationship between flow in Clear Creek and its water temperature regime under the hydrodynamic, meteorological, and operating conditions prevailing during critical periods of chinook salmon migration and rearing.

Objectives

The principal objective of this project is to quantify the relationship between water temperature and hydrodynamic conditions in Clear Creek from Whiskeytown Dam to the Sacramento River, over a range of environmental conditions suitable for salmon propagation. Specific objectives include: assembly and evaluation of relevant data; development and implementation of field monitoring surveys; adapting, calibrating and verifying mathematical models to simulate flows and temperatures; demonstration of the models' capabilities to predict Clear Creek's responses to changes in flow and water temperatures; and documentation of the data base, models and other attributes of the physical system and its operation that are relevant to maintenance and/or enhancement of salmon populations supported by Clear Creek.

Scope of Work and Schedule

It is proposed to meet the above stated objectives by adapting a set of existing hydrodynamic and water quality models to Clear Creek thereby providing the means to quantify the relationship(s) between flows and temperatures. These models, known as RMA2 (hydrodynamics) and RMA11 (water quality, including temperature) were developed, calibrated, verified and applied to the Sacramento and Feather rivers in a recently completed modeling project (Deas, et.al., 1996) and have been preliminarily adapted to Clear Creek in an investigation of the three-dimensional hydrodynamics of Whiskeytown Reservoir (UCD/USBR, 1996. The models utilize the finite element method to solve the equations of momentum and continuity (RMA2) and advection-dispersion (RMA11) for both steady and unsteady flow conditions. Output consists of temporal and spatial descriptions of velocities, flows, water levels and water temperatures over a grid representing the geomorphic characteristics of the stream channel.

Specific tasks include: (1) assembly and evaluation of data; (2) design and implementation of field surveys to complete the data base for modeling; (3) model adaptation to the specific geometry of Clear Creek; (4) calibration and verification of the models against field observations; (5) model application to predict flow-temperature relationships; and (6) project documentation, including the data base, models and other project accomplishments. It is expected that these tasks can be completed within one year from the start of the project.

Expected Benefits

The principal benefit of this project will be an enhanced, secure habitat for chinook salmon in Clear Creek. This benefit is expected to be realized by providing a unique capability to fisheries managers and project operators, in the form of calibrated mathematical models that can quantity the interrelationships between flows and temperatures.

Products

The principal products of this project will be flow-temperature relationships for Clear Creek that will assist fisheries managers and project operators to develop and maintain a healthy habitat for the propagation of chinook salmon. A detailed report documentiing project accomplishments will be provided.

Project Justification

Clear Creek has been an important contributor to salmon populations in the Sacramento River system, but its present capability is limited to the lower reaches where flows and temperatures conducive to salmon productivity are largely governed by project operation. This project will provide state-of-the-art tools to improve the reliability of temperature prediction as affected by flow regulation, thereby enhancing the prospect for salmon rearing success. Achievement of project goals will be greatly aided by utilizing existing calibrated and verified models from the Sacramento River Temperature Modeling Project and results of preliminary studies of Clear Creek in connection with hydrodynamic modeling of Whiskeytown Reservoir. By accessing products of prior studies and concurrent investigations work effort and costs to achieve this project's objectives will accordingly be reduced.

Budget Costs

It is estimated that the cost of the proposed project will not exceed $54,634.

Applicant Qualifications

This project is supported by many years of experience of the principal investigators, Drs. G. T. Orlob and I. P. King, in development and application of mathematical models for investigation of the hydrodynamic and water quality behavior of surface water systems. These have included modeling studies of many of the integral components of the Central Valley system, e.g., the Sacramento and Feather Rivers, Shasta, Trinity, Keswick, and Whiskeytown reservoirs, and the Sacramento-San Joaquin Delta. The models proposed for this project are original contributions of the principal investigators and their students at UC Davis. Graduate student participants in this project are experienced in modeling and field survey techniques.

Program Coordination

The proposed project will be coordinated with ongoing UC Davis research projects sponsored by USEPA, USBR, USFWS, California Departments of Fish and Game and Water Resources, and the State Water Resources Control Board.

FLOW-TEMPERATURE RELATIONSHIPS FOR CLEAR CREEK

Department of Civil and Environmental Engineering
University of California Davis

I. Project Description

Clear Creek is a tributary of the Sacramento River located in ShastaCounty. It joins the river's main stem about 12.5 river miles downstream of Keswick Dam and about 5 miles south of Redding (Figure 1). A major part of the creek's catchment that once was an important spawning habitat for chinook salmon was isolated in 1960 by construction of Whiskeytown Dam, a facility of the Shasta-Trinity Division of the Central Valley Project (CVP). Due to blockage of their natural migratory pathway, spawning of chinook salmon is now restricted to a short reach of the creek just below the dam where flows and temperatures are largely regulated. Because of loss of habitat upstream of the dam and factors influencing the quality of that below, this reach of the creek has become an especially important component in the overall maintenance and restoration of salmon habitat in the Upper Sacramento system. Critical concerns for winter and spring run salmon in this environment are maintenance of flows favorable to upstream migration of adults and out-migration of juveniles, and maintenance of water temperatures that will assure spawning success. The relationships between flow and temperature in the 16-mile reach of Clear Creek below Whiskeytown Dam are the principal subjects of this proposal.

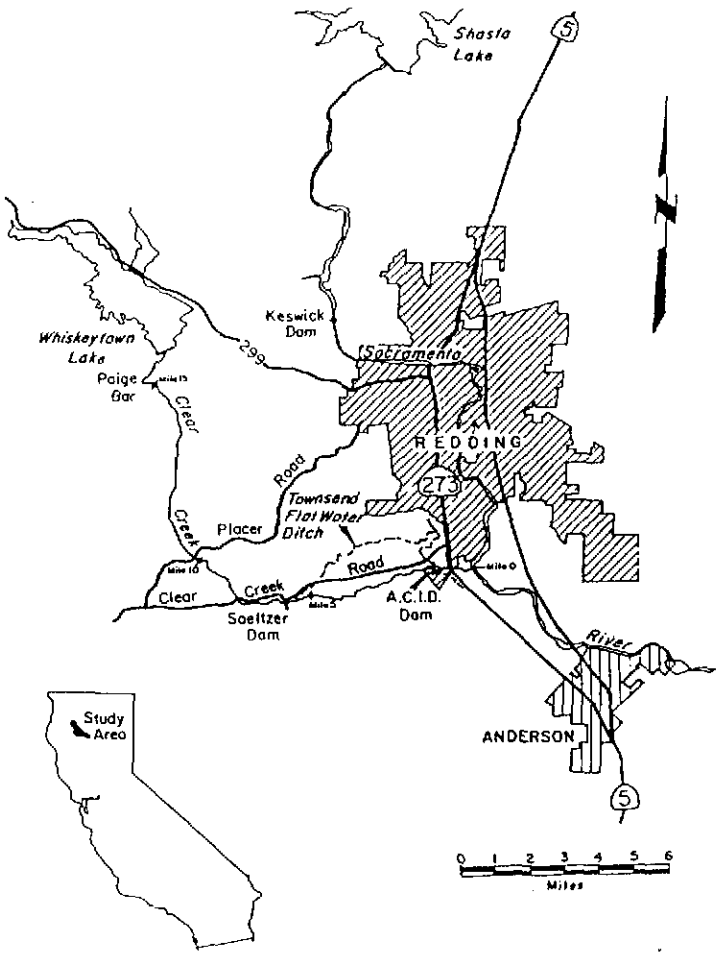

Figure 1 Location Map, Clear Creek Modeling Project

Water temperatures of releases from Whiskeytown Dam to Clear Creek are governed primarily by operation of the Shasta-Trinity Division of the CVP which transfers water from Trinity Lake through Whiskeytown Reservoir to augment water supplied to the Central Valley. A major portion of the water released from the reservoir is diverted to Keswick Reservoir through the Spring Creek Power Plant; only minimum flows for sustenance of salmon are released to Clear Creek. Thermal stratification in the reservoir, regulated to some degree by temperature control curtains near the inlet and near the headworks of the Spring Creek Tunnel, is a major factor governing the temperatures of releases to both Clear and Spring creeks, the only outlets of the reservoir. Downstream of Whiskeytown Dam in the Clear Creek channel, changes in water temperature from that at the upstream boundary are determined largely by heat exchanges through the air-water interface and accretions or depletions of ground and surface waters. Likewise, flows in the creek are determined by releases at the dam and accretions and depletions along the creek's 16-mile route to its confluence with the Sacramento River. Because flow in the creek is variable, subject to regulation at the dam as well as by natural hydrologic variation, there is an implicit dependence of water temperature on flow, i.e., on the hydrodynamics of the creek. In the interest of enhancing salmon propagation success in Clear Creek the relationship between these two environmental characteristics needs to be explicitly defined. Such definition will assist project operators and fisheries managers in determining the rates and timing of releases from Whiskeytown Dam to enhance spawning habitat.

II. Project Objectives

The principal objective of this project is to quantify the relationship between water temperatures and hydrodynamic conditions in Clear Creek from Whiskeytown Dam to the Sacramento River, over a range of environmental conditions suitable for salmon propagation. It is proposed that this objective be achieved by utilizing mathematical models that were previously developed, calibrated, and applied in the Sacramento River Temperature Modeling Study (Deas et.al, 1996).

Specific objectives of the proposed project are as follows:

1. to assemble and evaluate existing hydrologic, geomorphic, atmospheric, water temperature, and reservoir operation data relevant to hydrodynamic and temperature modeling of Clear Creek and determine data deficiencies,
2. to design and implement field programs and surveys to supplement existing data on geomorphology of the creek, water temperatures, flows, and meteorological conditions,
3. to adapt, calibrate, and verify existing mathematical models to simulate hydrodynamics and temperatures in Clear Creek over a range of realistic operating conditions of the Shasta-Trinity Division of the CVP,
4. to utilize results of modeling to develop the relationships between flows and temperatures in Clear Creek as functions of project operation and meteorological conditions corresponding to the critical periods of salmon propagation,
5. to document the basic morphological, hydrological, meteorological and other attributes of Clear Creek related to maintenance and/or enhancement of salmon populations.

III. Proposed Scope of Work

To meet the objectives listed above the following tasks must be completed.

Task 1: Data Acquisition and Evaluation

Purpose: To provide data and information necessary to develop an enhanced understanding of the flow and temperature characteristics of Clear Creek. Specific attention will be given to data needs to construct, calibrate and apply mathematical hydrodynamic and water quality models of Clear Creek.

Essential data include channel cross-sections, channel gradients, water temperatures, flows, and meteorological conditions. Some channel cross-section data provided by the Department of Water Resources have been useful in preliminary structuring of the models, but these data are not current nor sufficient in coverage of the creek channel, especially in the upper 5 miles or so of the creek where channel walls are steep and irregular. Moreover, recent flood events have modified the channel's configuration in its lower reaches, requiring resurvey.

Water temperature data are sparse, limited to a few short records obtained from continuous sensors in the middle reaches of the creek. An example is shown in Figure 2. Unfortunately, these data are not accompanied by reliable flow data. There is a need to develop simultaneous observations of temperature and flow over the flow range of interest, say for flows from 50 to 300 cfs. Meteorological observations required for estimation of heat exchange through the air-water interface are available at nearby locations, e.g., Redding Airport. A met station soon to be installed near Whiskeytown Reservoir in the related hydrodynamic modeling project (UCD/USBR, 1996) is expected to provide the additional data on air temperatures, wind, relative humidity and solar radiation required for estimation of net heat flux across the air-water interface.

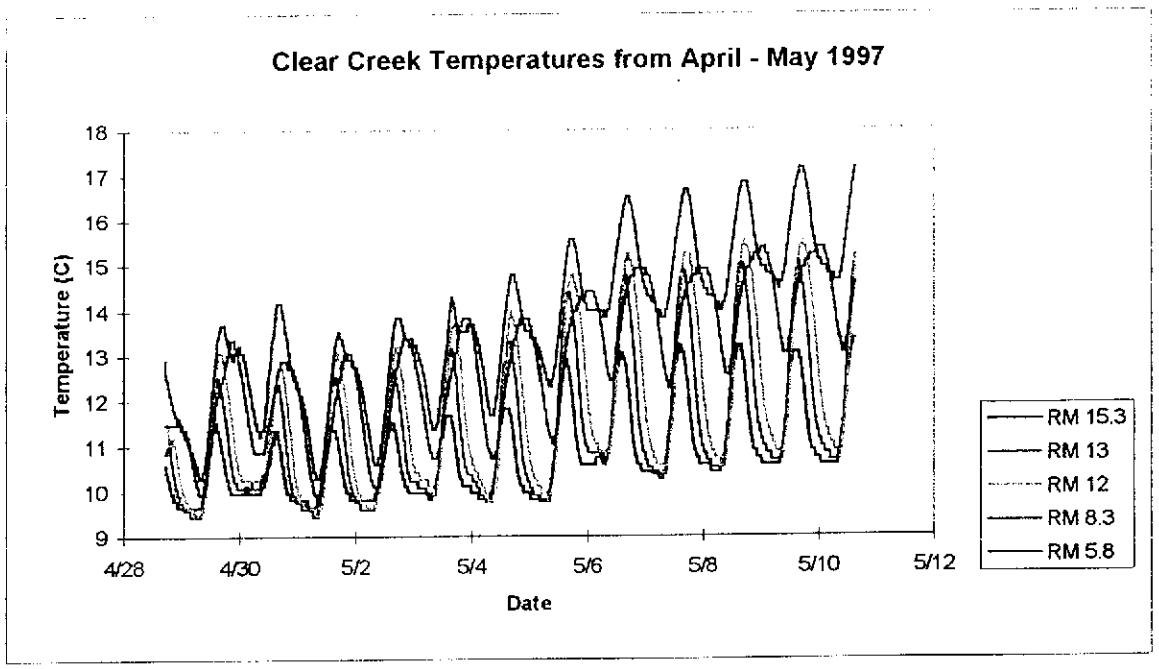

Figure 2 Water Temperatures at Five Locations Along Clear Creek

Task 2: Design and Implementation of Field Monitoring Program

Purpose: To obtain a complete description of physical, hydrological and meteorological conditions in the Clear Creek system.

It is proposed to conduct field monitoring of water temperatures by deploying continuous recording sensors, e.g., Onset Instruments or equivalent, at 6 to 8 stations along the creek. These stations will be operated for periods of up to five months spanning the summer season. Data collected will be supplemented by observations of the California Department of Fish and Game (DFG). A goal of this effort will be development of records, such as that shown in Figure 2, describing both temporal and spatial variations in temperature of Clear Creek coincident with information on stream flows.

Field surveys of flows will be conducted on at least two occasions during this same period under conditions of steady controlled releases from the reservoir arranged by agreement with USBR project operators. Information from these surveys will include both instantaneous flows and cross-sections in sufficient detail to describe flow variations along the 16-mile reach of the creek. A Marsh-McBirney flow meter is available for these surveys at no cost to the project. Additional data on stream channel morphology, local topography, and riparian vegetation shading along the channel will be developed using global positioning satellite (GPS) instrumentation, also available without cost for this project.

Meteorological data required for modeling includes dry and wet bulb air temperatures, relative humidity, wind velocity and cloud cover. These will be derived from continuous observations at the Whiskeytown Met Station to be installed in connection with hydrodynamic modeling of the reservoir (UCD/USB 1996) and at the Redding Airport Station which has been accessed in previous water temperature modeling projects (Deas, et.al, 1996).

Task 3: Model Adaptation

Purpose: To adapt existing hydrodynamic and temperature models to Clear Creek

A first step in model adaptation is the construction of a finite element grid. A preliminary grid has already been developed in connection with the Whiskeytown modeling project, but it needs refinement in geometric representation of the Clear Creek channel, especially in the upper reaches where the channel's configuration is still uncertain. Field measurement of flows will provide additional information on cross sections. However, the initial grid, developed from prior surveys by DWR, provides a good base from which the final grid may be developed. Once a suitable grid is developed and refined to assure stability in hydrodynamic computation, the models may be calibrated and verified against field observations.

It is proposed to utilize two finite element models, known as RMA2 (hydrodynamics) and RMA11 (water quality) to simulate the flow-temperature regime of Clear Creek. RMA2 is a mathematical model that solves the hydrodynamic equations of momentum and continuity over the grid space using the finite element method. The model provides both steady state and dynamic descriptions of velocities, flows, and water levels for a discretized system of elements representing the physical system. A preliminary simulation showing variations in velocity and water depth along Clear Creek under conditions of a steady flow is illustrated in Figure 3. Information derived from RMA2 will be provided as input to RMA11, a companion water quality model that simulates the dynamics of temperature change with flow and meteorological conditions. Results from RMA11 will be in the form of time series of water temperatures at selected locations, as illustrated in Figure 2 above.

These models were developed, calibrated, verified and successfully applied to the main stems of the Sacramento and Feather rivers in the recently completed Sacramento River Modeling Study . As noted above, they have also been adapted to Clear Creek in a preliminary study related to the Whiskeytown hydrodynamic modeling project, but they have not been calibrated nor verified for lack of reliable field data, such as is proposed to be acquired in this project.

Task 4: Calibration and Verification of Clear Creek Models

Purpose: To calibrate and verify models against field observations of flows and temperatures

It is proposed to develop at least two sets of data, one each for calibration and verification. In the calibration exercise adjustments in channel roughness (Manning's n) will be used to confirm the model's ability to simulate the observed flows. Water temperature simulations will be adjusted using the heat budget parameters incorporated in RMA11 as

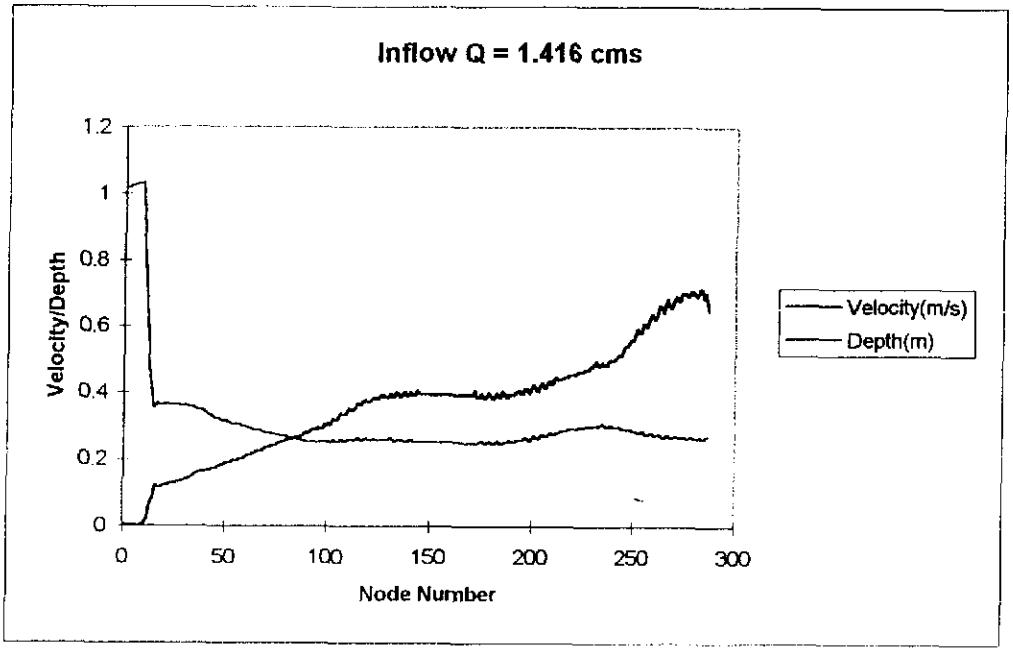

Figure 3 Simulated Velocities and Depths Along Clear Creek, Preliminary Study

described in Deas, et.al.(1996). A test of the calibrated model is its ability to produce a comparably reliable result with a new set of boundary condition data, e.g., inflows and heat fluxes, without changing the calibration parameters and coefficients. Experience in modeling the Sacramento River System has shown that the two models can be used in tandem to improve calibration, since the phase of the simulated diurnal pattern of temperature (Figure 2) is dependent upon the flow velocity derived from the hydrodynamic model. Channel roughness adjustment within a reasonable range typical of steep channels such as Clear Creek may be used to assure agreement between the predicted and observed diurnal temperature patterns. Products of this task will be verified hydrodynamic and temperature models available for application to problems of extreme hydrological and meteorological conditions likely to impose stress on aquatic species.

Task 5: Model Application, Flow-Temperature Relationships

Purpose: To predict Clear Creek water temperatures as functions of flow and meteorological conditions

Once verified the models may be applied to predict water temperature response as a function of flow released at Whiskeytown Dam, or any other control location, given specified meteorological boundary conditions. The sensitivity of the model to variations in parameters, coefficients and boundary conditions can be developed in an organized program of simulations. A product of such "sensitivity testing" may be in the form of a matrix of possible solutions, i.e., flows and temperatures. These solutions may serve to guide operation of temperature control facilities to assure satisfactory flows and temperatures for salmon propagation. A sensitivity matrix will be provided as a product of this task.

Task 6: Project Documentation

Purpose: To document flow-temperature relationships for the Clear Creek environment, and other project accomplishments

A detailed report covering all aspects of the project, including basic data, will be submitted at the conclusion of the project.

IV. Expected Benefits

The principal expected benefit of this project will be an enhanced understanding of the necessary conditions for the long term propagation of Chinook salmon in Clear Creek. This goal is expected to be achieved by providing a unique capability to fisheries managers and project operators in the form of calibrated mathematical models that can quantify the interrelationships between flows and water temperatures in Clear Creek. Collateral benefits of the project may be in several forms, as follows:

1. a detailed characterization of the physical environment of Clear Creek, including stream morphology , riparian habitat and operational facilities,

2. a data base of physical, hydrologic, hydrodynamic, meteorologic and water temperature characteristics of the Clear Creek environment,

3. a characterization of the Clear Creek environment in quantitative terms of flows and water temperatures for any given set of hydrologic, meteorologic or project operation boundary conditions,

4. a means for determining the best operating schedule for releases from Whiskeytown Reservoir that will assure maintenance of a healthy habitat for Chinook salmon propagation throughout Clear Creek,

5. a means to quantify the effects of physical or operational changes in the Clear Creek-Whiskeytown system on the flow and temperature regimes of Clear Creek, and

6. an enhanced habitat for long term propagation of salmon in Clear Creek.

V. Products

The principal products of this project will be flow-temperature relationships for Clear Creek derived by applying hydrodynamic and temperature models and utilizing the supporting data base of physical, hydrological, and meteorological information that characterizes the Clear Creek environment for salmon. A detailed final report will be provided to document the project's accomplishments.

VI. References Cited

Deas, M., et.al, Sacramento River Temperature Modeling Project, Final Report to State Water Resources Control Board, December 1996

UCD/USBR, Temperature Regulation Through Whiskeytown Reservoir, Investigation in progress, 9/1/96 - 8/31/98

Budget Costs

A.	Personnel	
	1. Principal investigator; 12 mo. @ 10% (no charge)	$ 0
	2. Co-principal investigator, advisor; occasional	0
	3. PGRE IV, student; $2652; 12mo. @75%	23,868
	4. Undergraduate assistant; 3 mo. @ $1000, 9 mo. @ $400	6,600
	Subtotal, personnel	$30,468
B.	Fringe Benefits	
	0.038 x (A3 + A4)	$ 1,158
	Subtotal, benefits	1,158
C.	Student Fees	$ 4,485
D.	Travel	1,000
E.	Supplies	1,000
F.	Equipment: Temperature Sensors	1,560
G.	Overhead 0.445 x (A + B + D + E) (out-of state or federal contract rate)	$14,963
	Total proposed budget	$54,634

Schedule Milestones

The proposed project is planned for a duration of one year following execution of an agreement. Field work will be performed during the summer period. Progress reports will be delivered to the sponsor at quarterly intervals following the start of the project and a draft final report will be submitted 1.5 months before the terminal date of the project. A final report will be delivered upon completion of all work. Payment for work completed will be due upon submittal of quarterly invoices.

Third Party Impacts

The work proposed for this project addresses an indicated need of fisheries managers of the California Department of Fish and Game, which agency has already provided useful data and other information relative to flows, temperatures, and salmon habitat in Clear Creek. Additionally, the project is complementary of an ongoing investigation of the three-dimensional hydrodynamics of Whiskeytown Reservoir sponsored by the U. S. Bureau of Reclamation. It is expected to provide improved understanding of the operational effects on Clear Creek of Shasta-Trinity water transfers. Sharing of information on flows, temperatures and meteorological conditons between the two projects is expected to enhance the productivity of both.

Applicant Qualifications

This project is an outgrowth of a series of research and development projects conceived and directed by the principal investigators, both in consulting engineering practice and at the University of California Davis. This activity has resulted in the development of original mathematical models for the simulation of hydrodynamics and water quality in surface water systems, rivers, lakes, reservoirs, estuaries, and coastal waters. Among these are models that have been applied to many of the surface water bodies of concern in the Cal-Fed Program including the Sacramento and Feather rivers, Shasta, Trinity, and Keswick reservoirs, Clear Lake, the Sacramento-San Joaquin Delta, and San Francisco Bay. Most recently three of these models: RMA2, RMA11 (proposed to be used in this project) and WQRRS, were adapted and applied to the Sacramento and Feather river systems from their upstream impoundments to the Delta for simulation of hydrodynamics and temperatures (Deas, et.al. 1996). In related

investigations these models are being extended and applied to the Delta under support from the National Science Foundation and the Environmental Protection Agency and to Whiskeytown Reservoir in a project funded by the U.S. Bureau of Reclamation. The major part of this work has been carried out by graduate student researchers in the Water Resources and Environmental Engineering Modeling Group of the Department of Civil and Environmental Engineering at UC Davis.

The proposed project will be directed by Dr. G. T. Orlob, Professor Emeritus of Civil and Environmental Engineering, as Principal Investigator. Dr. Ian P. King, Professor of Civil and Environmental Engineering, and an original developer of the models proposed for simulation of Clear Creek, will serve as an advisor on modeling applications. Both Drs. Orlob and King will serve without cost to the project. Ms. Xiaochun Wang, doctoral candidate at UC Davis, will serve as project engineer-manager. An undergraduate student assistant will provide support in data collection and analysis. Brief biosketches of the PIs and Ms. Wang are provided below.

Gerald T. Orlob, Principal Investigator

Dr. Orlob is presently Professor Emeritus of Civil and Environmental Engineering at the University of California at Davis. He holds degrees in civil, environmental and hydraulic engineering and is a registered professional engineer in California. Throughout a career in professional practice, engineering education, and research he has specialized in the development and application of systems analysis techniques, especially mathematical models of surface water systems, for water quality management. He has published widely in the technical literature. His contributions in his field of specialization have been recognized by awards from professional and scientific organizations and election to the National Academy of Engineering and to Honorary Membership in the American Society of Civil Engineering. As an emeritus professor he continues active participation in research related to water quality issues, recently focused on temperature control in northern California river systems, e.g., Sacramento, Trinity, Feather, Shasta, and Klamath rivers, and the Sacramento-San Joaquin Delta.

Ian P. King

Dr. King is Professor of Civil and Environmental Engineering at the University of California at Davis. He holds BS and MS degrees in structural engineering and a doctorate in engineering mechanics. In addition to teaching and research related to hydromechanics and water quality, Dr, King has wide experience in private professional practice concerned with the development and application of mathematical models for simulation of surface water systems. He is the original developer of a suite of finite element models that are being widely applied to characterize the hydrodynamic and water quality behavior of rivers, lakes and reservoirs, estuaries and the coastal environment. At UC Davis he teaches in the graduate programs of water resources and environmental engineering and is engaged with his students in research related to water resources management. His recent research has been concerned with extension of the finite element numerical method to solution of complex three-dimensional flow fields.

Xiaochun Wang

Ms. Wang is a graduate student in the doctoral programs of water resources and environmental engineering at the University of California at Davis. She has completed all course work for a Ph.D. degree and will advance to candidacy in the fall of 1997. She is experienced in the application of finite element models for simulation of hydrodynamics, sediment transport and temperatures in both riverine and estuarine systems. Ms. Wang has served as project engineer on projects concerned with climate change effects on water quality in Shasta Lake, temperature simulation of Trinity Reservoir, restoration of marshlands in San Pablo Bay, and application of a two-dimensional hydrodynamic model for investigation of sediment transport in the Delta. In a preliminary study related to the Whiskeytown project she adapted RMA2 and RMA11 to Clear Creek to establish the feasibility of employing the models to determine flow-temperature relationships.

Item 8

NONDISCRIMINATION COMPLIANCE STATEMENT

COMPANY NAME: THE REGENTS OF THE UNIVERSITY OF CALIFORNIA

The company named above (hereinafter referred to as "prospective contractor") hereby certifies, unless specifically exempted, compliance with Government Code Section 12990 (a-f) and California Code of Regulations, Title 2, Division 4, Chapter 5 in matters relating to reporting requirements and the development, implementation and maintenance of a Nondiscrimination Program. Prospective contractor agrees not to unlawfully discriminate, harass or allow harassment against any employee or applicant for employment because of sex, race, color, ancestry, religious creed, national origin, disability (including HIV and AIDS), medical condition (cancer), age, marital status, denial of family and medical care leave and denial of pregnancy disability leave.

CERTIFICATION

I, the official named below, hereby swear that I am duly authorized to legally bind the prospective contractor to the above described certification. I am fully aware that this certification, executed on the date and in the county below, is made under penalty of perjury under the laws of the State of California

OFFICIAL'S NAME: Sandra M. Dowdy
Contracts and Grants Analyst

DATE EXECUTED: JUL 25 1991

EXECUTED IN THE COUNTY OF: Yolo

PROSPECTIVE CONTRACTOR'S SIGNATURE: Sandra M. Dowdy

PROSPECTIVE CONTRACTOR'S TITLE:

PROSPECTIVE CONTRACTOR'S LEGAL BUSINESS NAME: THE REGENTS OF THE UNIVERSITY OF CALIFORNIA

I-005758